Path loss compensated pattern diversity antennas for mmWave 5G indoor base stations

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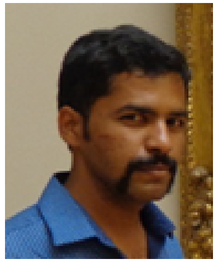
Abstract

A tapered slot antenna integrated with metamaterial unit cells and dielectric loading is proposed in this paper. The impedance bandwidth is 27-29 GHz (7.2%) with a forward gain of 12 dBi and a high aperture efficiency of 75%. In order to achieve uniform received power on the ground, antenna elements with 3 dB higher gain are necessary for beams oriented at ±45°, hence a compact co-polarized topology of pattern diversity is proposed to achieve a wide angle coverage of ±65° with path loss compensation. Detailed simulation and measurement results are presented.

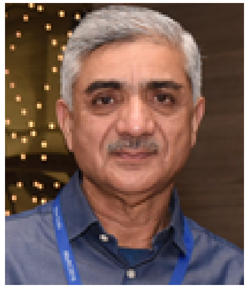
Index Terms— path loss compensation, mmWave 5G base station, high aperture efficiency

Biography



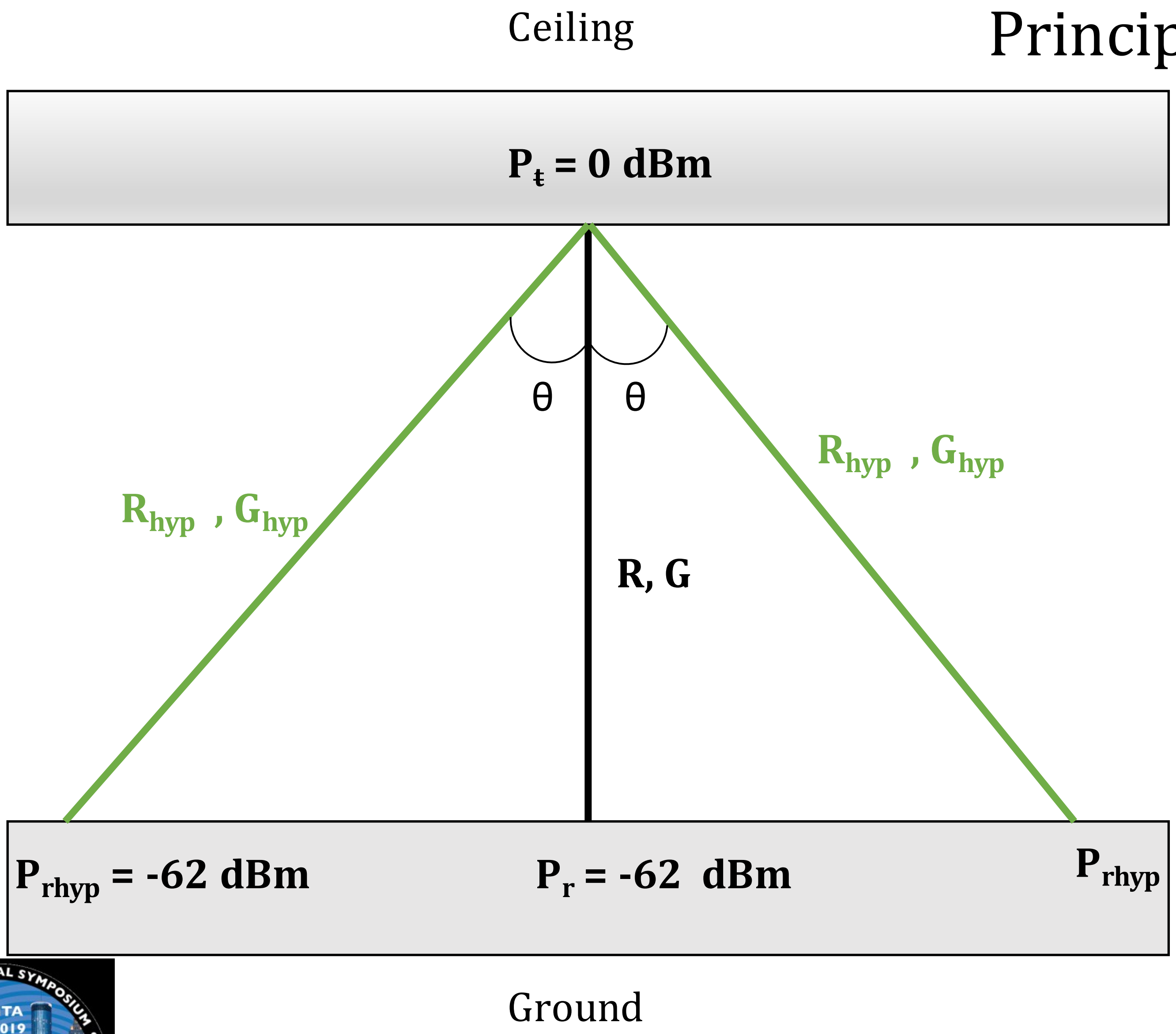
KARTHIKEYA G. S (S'–07) He worked as an assistant professor in Visvesvaraya technological university from 2013 to 2016. He completed his PhD from IIT Delhi in December 2019. He has authored or co-authored more than twenty five articles in peer-reviewed journals and conference proceedings. He has also filed three Indian patents. His research interests include mmWave antennas for mobile terminals and base stations.

MAHESH P. ABEGAONKAR (M'08–SM'13) received his PhD in physics (microwaves) from University of Pune in 2002. He worked as a post-doctoral researcher and an assistant professor at Kyungpook National University Daegu, South Korea during 2002--2005. Currently, he is an associate professor at the Centre for Applied Research in Electronics (CARE), Indian Institute of Technology (IIT) Delhi.



Shiban Kishen Koul (shiban_koul@hotmail.com) is currently serving as an Emeritus Professor at the Centre for Applied Research in Electronics, IIT Delhi. He served as the Chairman of M/S Astra Microwave Pvt. Ltd, a major private company involved in the Development of RF and Microwave systems in India from 2009-2019. His research interests include: RF MEMS, High Frequency Wireless Communication, Microwave Engineering, Microwave Passive and Active Circuits, Device modeling, Millimeter wave IC design and Reconfigurable microwave circuits including antennas. Dr. Koul is a Life Fellow of the IEEE.

Principle of path loss compensation


Ceiling
P_t = 0 dBm
θ
θ
R_{hyp} , G_{hyp}
R_{hyp} , G_{hyp}
R, G
P_{rhyp} = -62 dBm
P_r = -62 dBm
P_{rhyp}
Ground

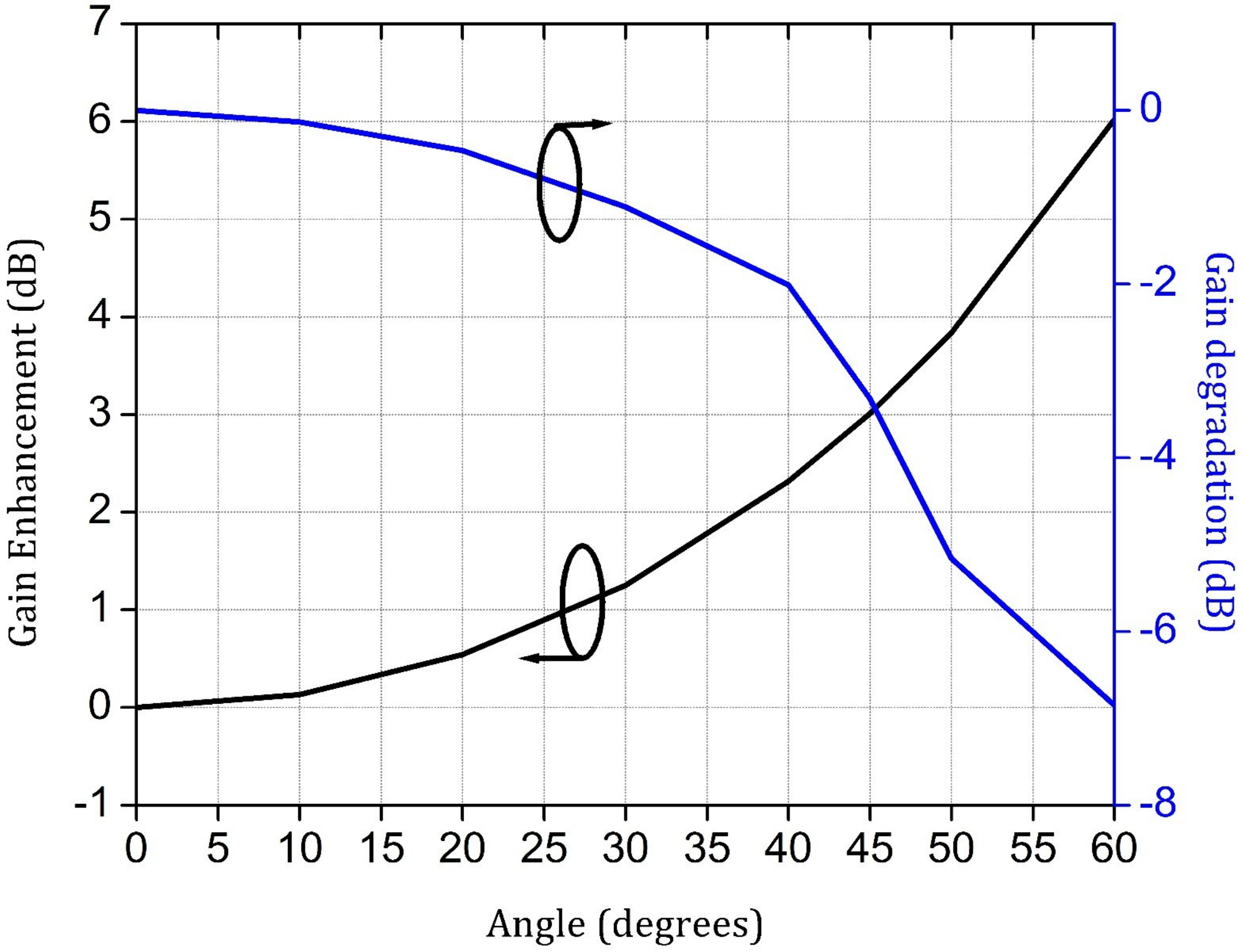
$$P_{rhyp} = P_r$$

$$P_{rhyp} = (P_t\, G_{hyp}\, G_r\, \lambda^2)/\,(4\pi R_{hyp})^2$$

$$G_{hyp}/G = (R_{hyp}/R\,)^2 = \sec^2\theta$$

$$G_{hyp}\,(dB) = G(dB) + 20\log(\sec\theta)$$

Gain requirements for Path loss compensation



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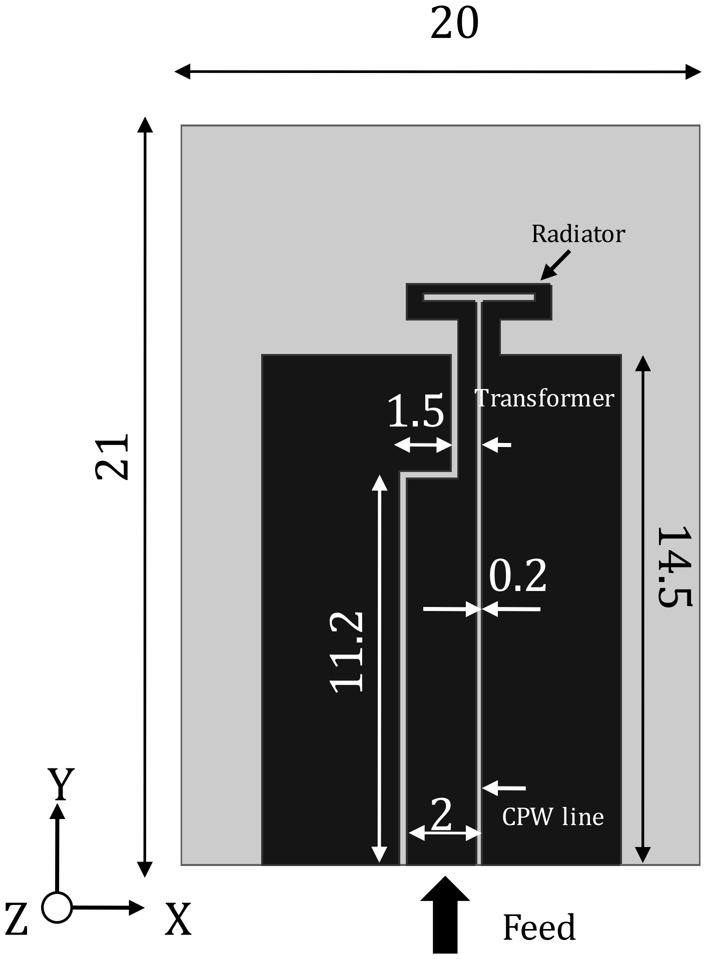
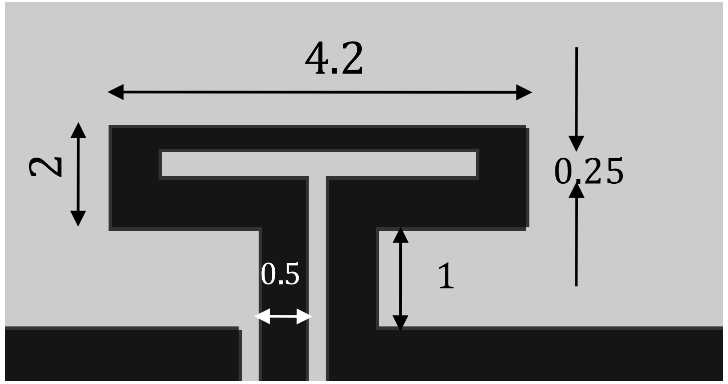
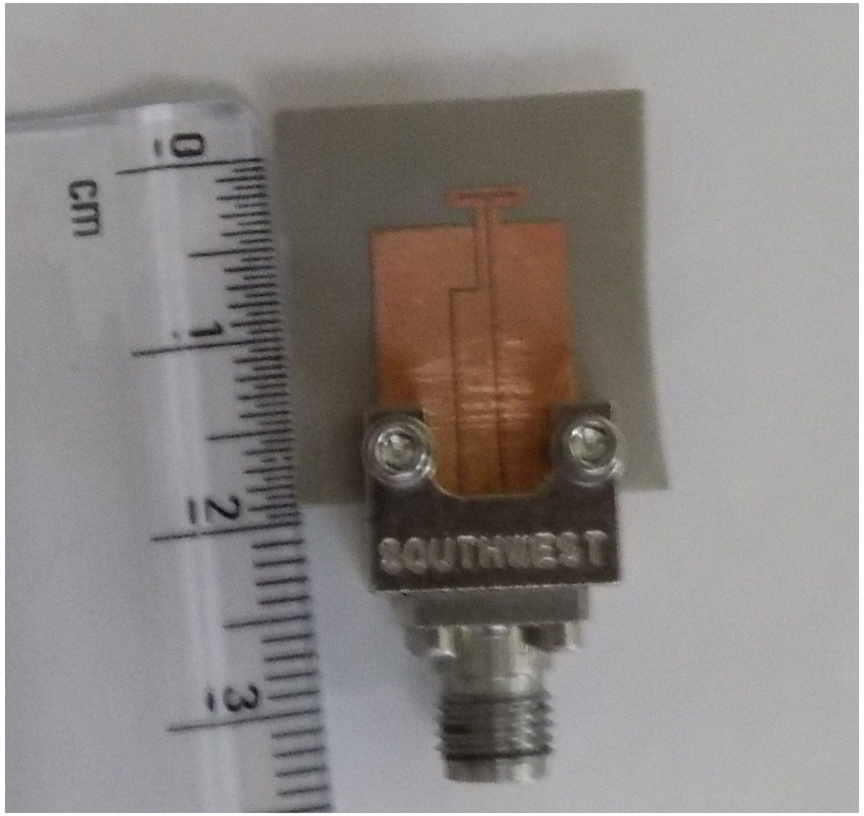
Central element : CPW fed folded dipole

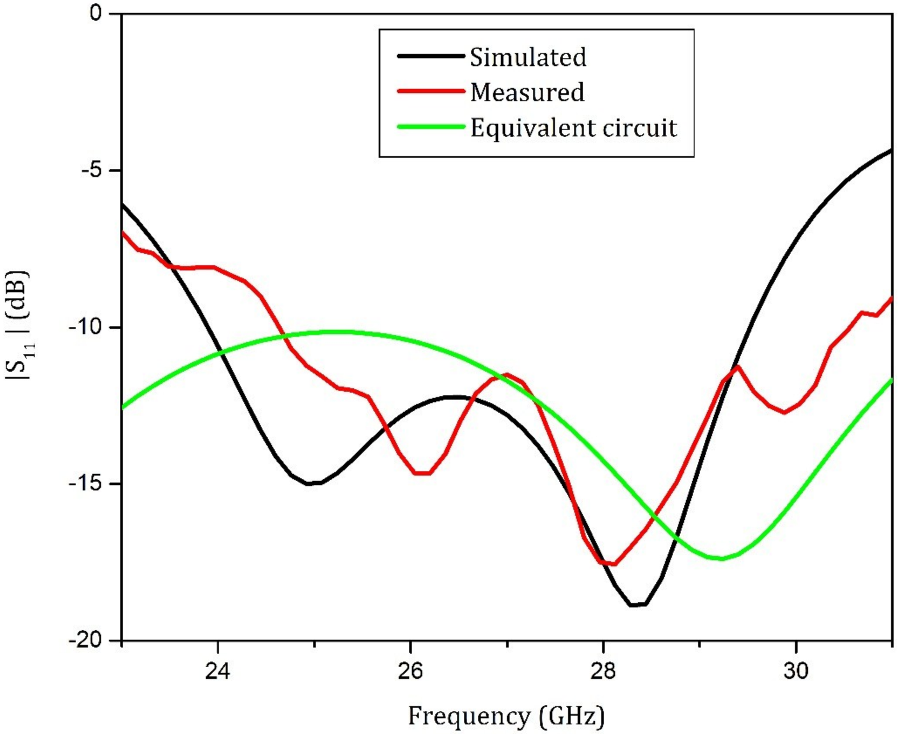

20
21
Radiator
1.5
Transformer
0.2
11.2
14.5
2
CPW line
Y
Z
X
Feed



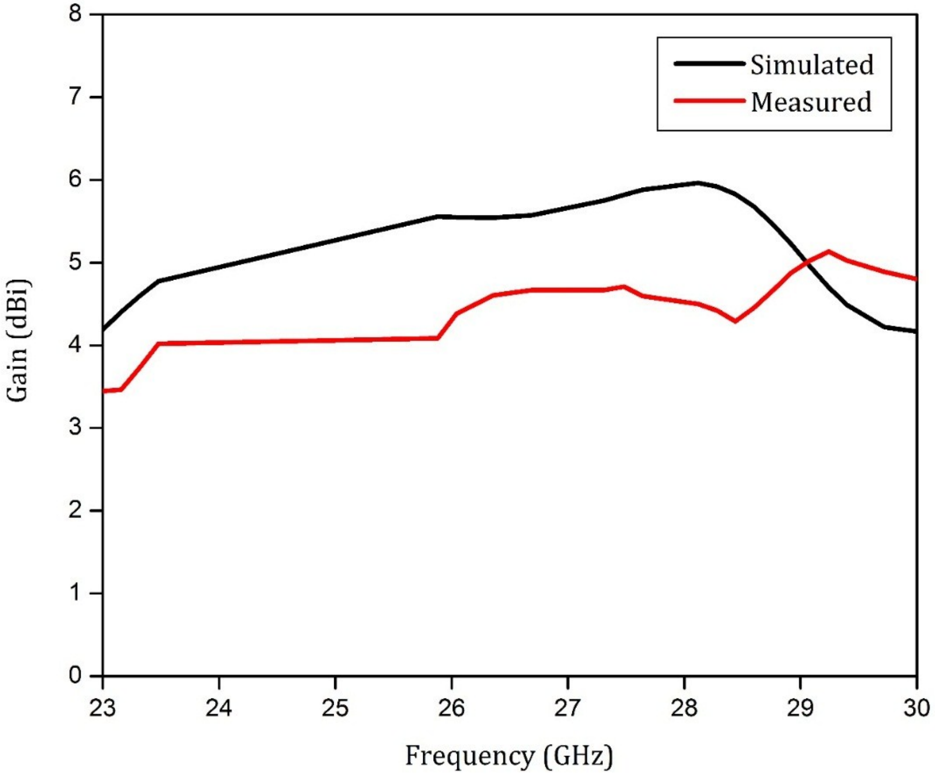

cm
0
1
2
3
SOUTHWEST

G. S. Karthikeya, M. P. Abegaonkar, and S. K. Koul, "CPW Fed Conformal Folded Dipole with Pattern Diversity for 5G Mobile Terminals," *Progress In Electromagnetics Research C*, Vol. 87, 199-212, 2018.

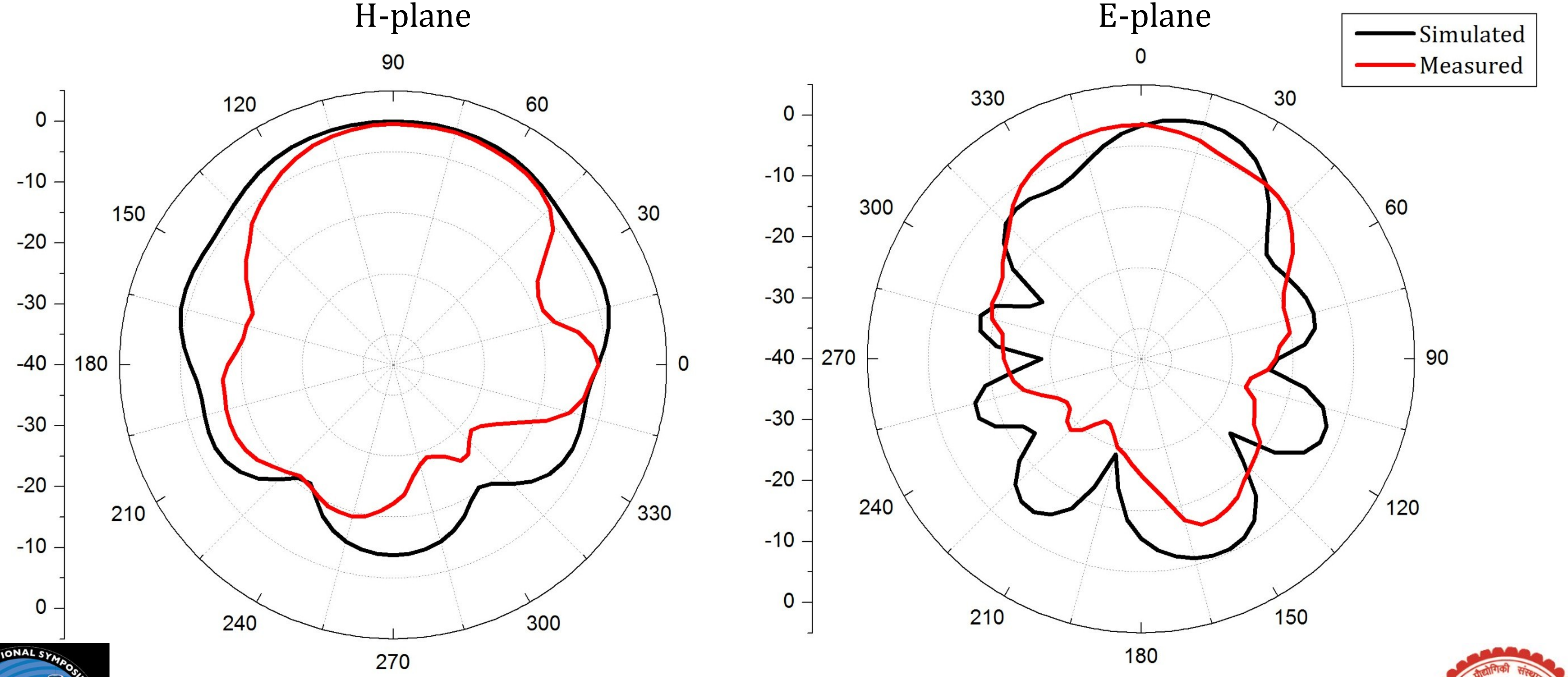
Input Reflection Coefficient



Forward Gain



Radiation Patterns at 28 GHz



H-plane

E-plane

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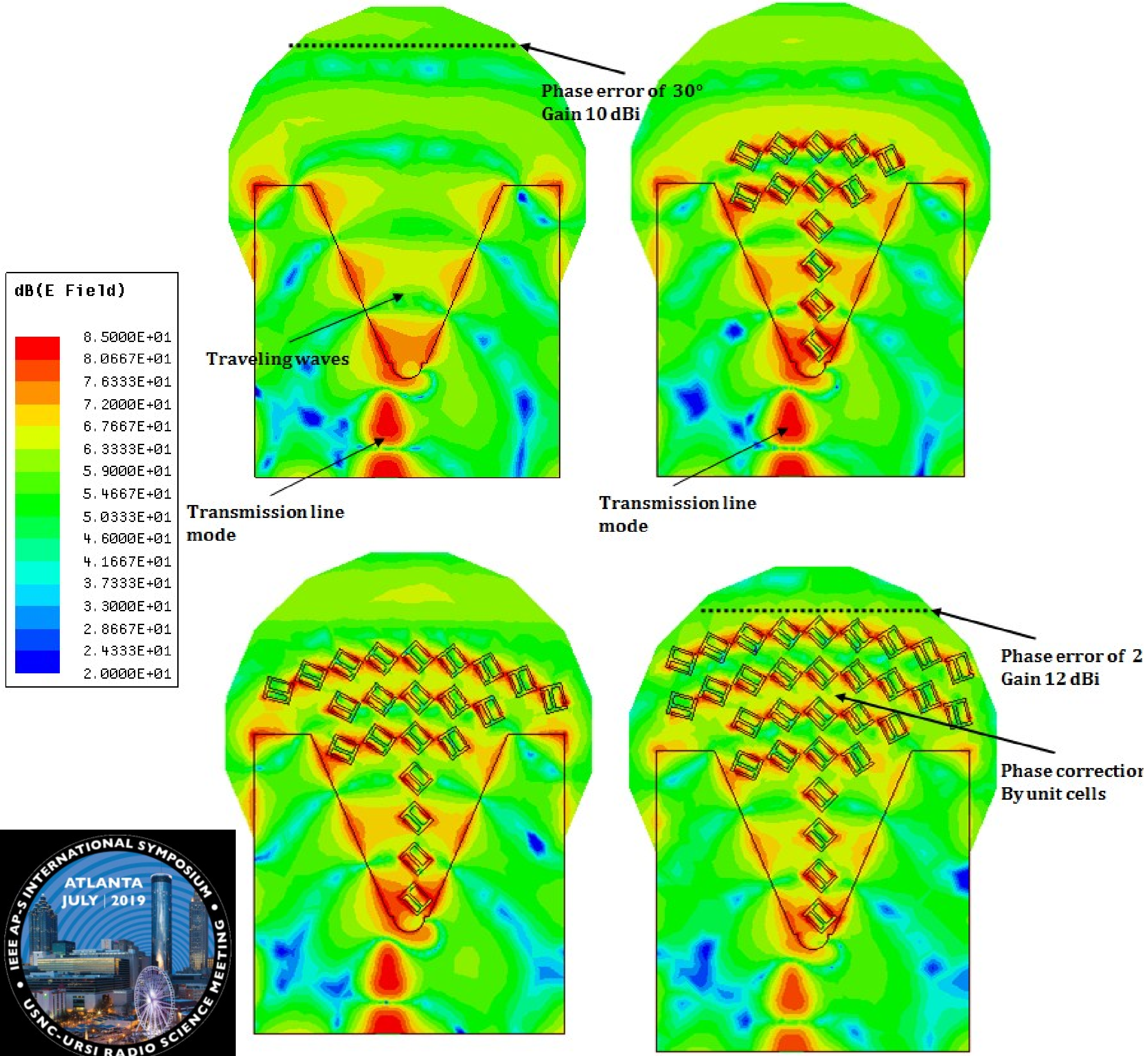
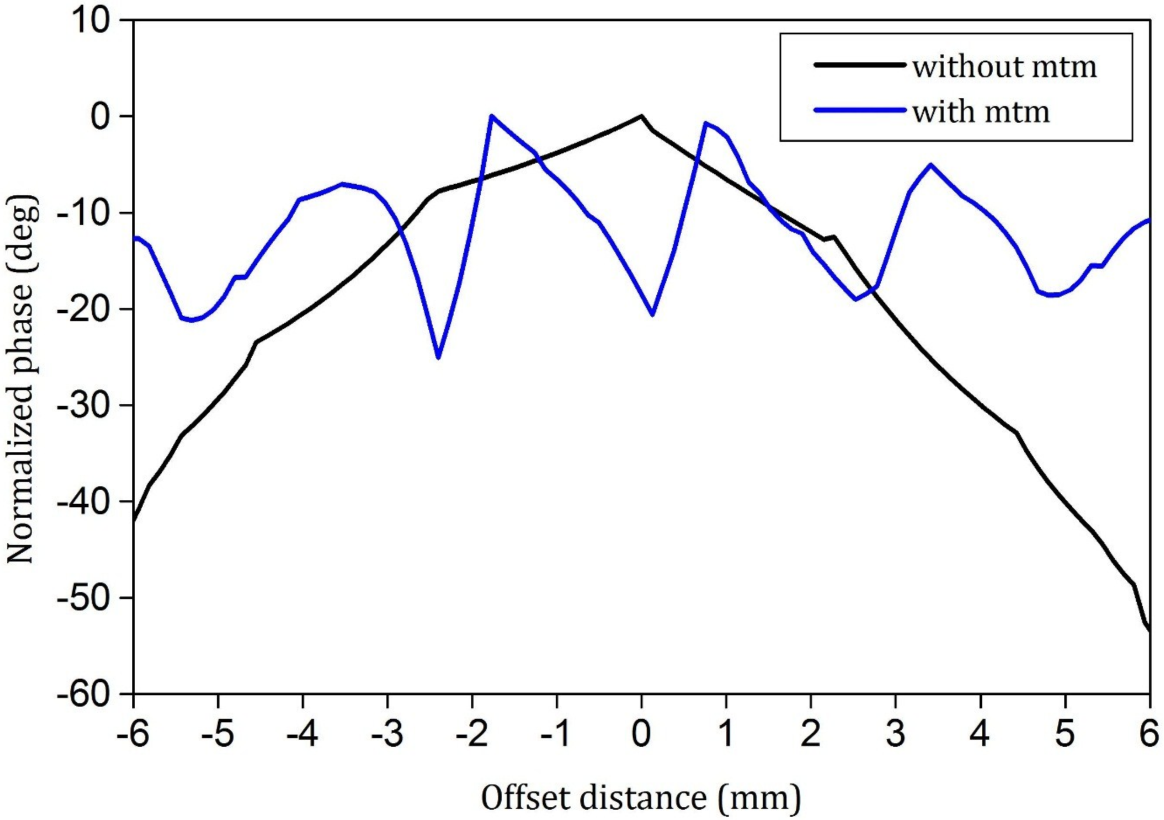
Tapered slot antenna with dielectric and metamaterial loading

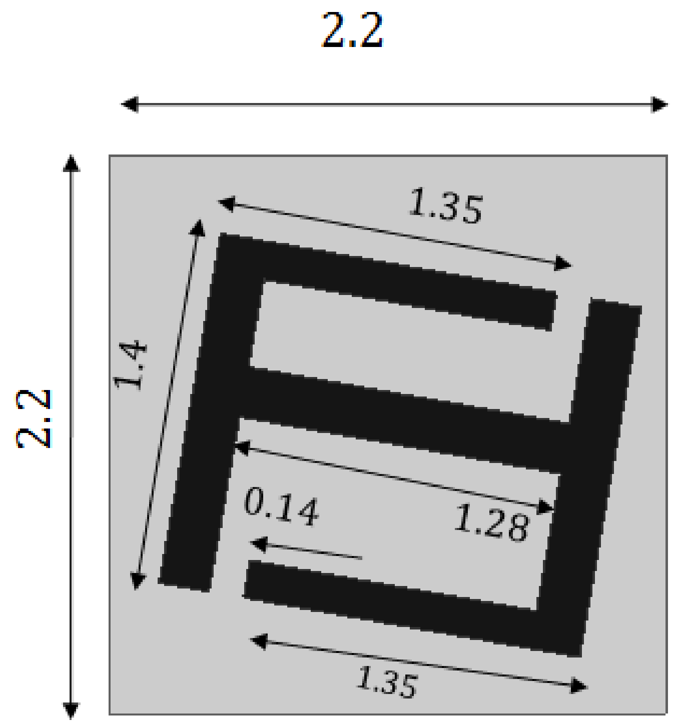
E-field of design evolution at 28 GHz

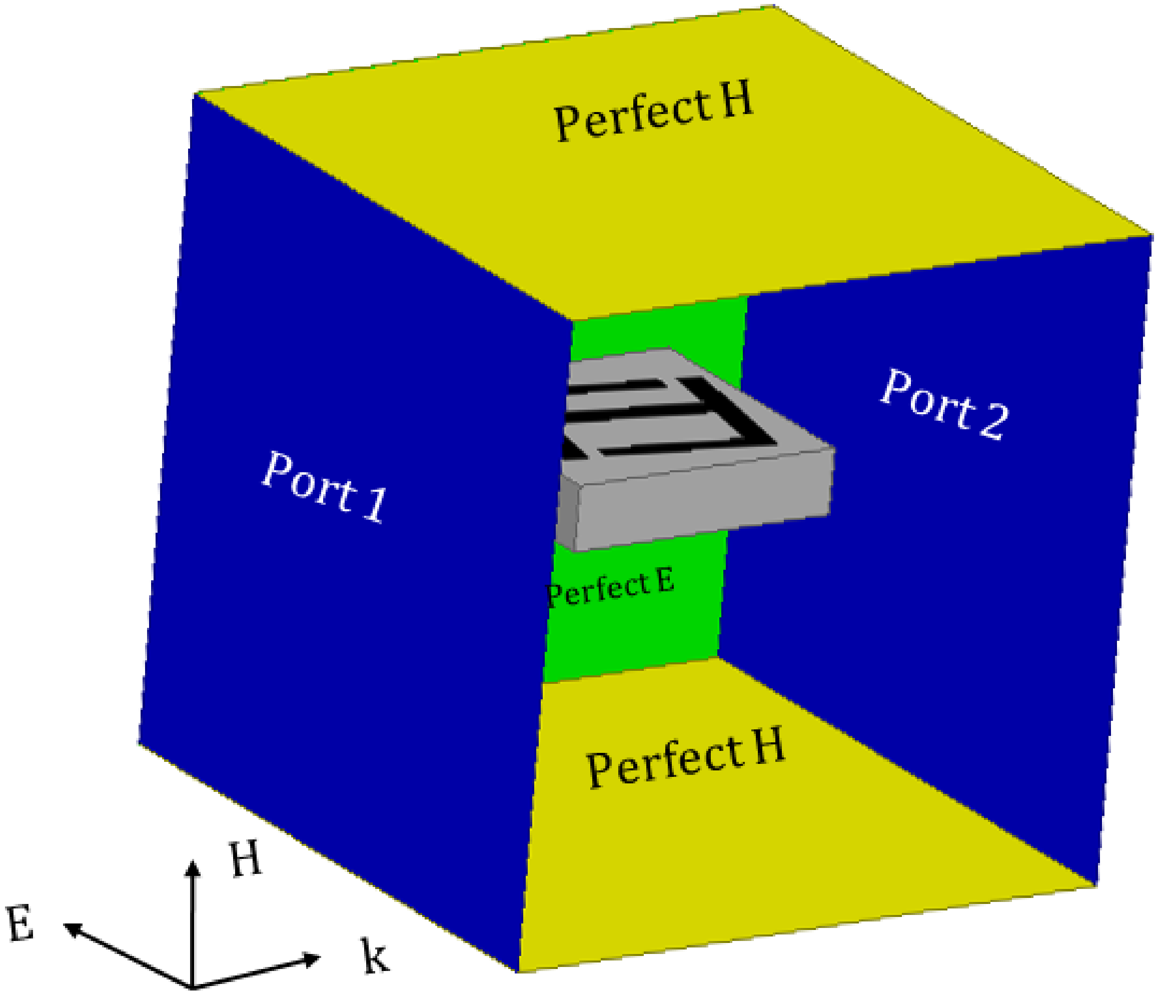

dB(E Field)
8.5000E+01
8.0667E+01
7.6333E+01
7.2000E+01
6.7667E+01
6.3333E+01
5.9000E+01
5.4667E+01
5.0333E+01
4.6000E+01
4.1667E+01
3.7333E+01
3.3000E+01
2.8667E+01
2.4333E+01
2.0000E+01
Phase error of 30°
Gain 10 dBi
Traveling waves
Transmission line mode
Transmission line mode
Phase error of 2
Gain 12 dBi
Phase correctio
By unit cells

Phase Linearization at 28 GHz



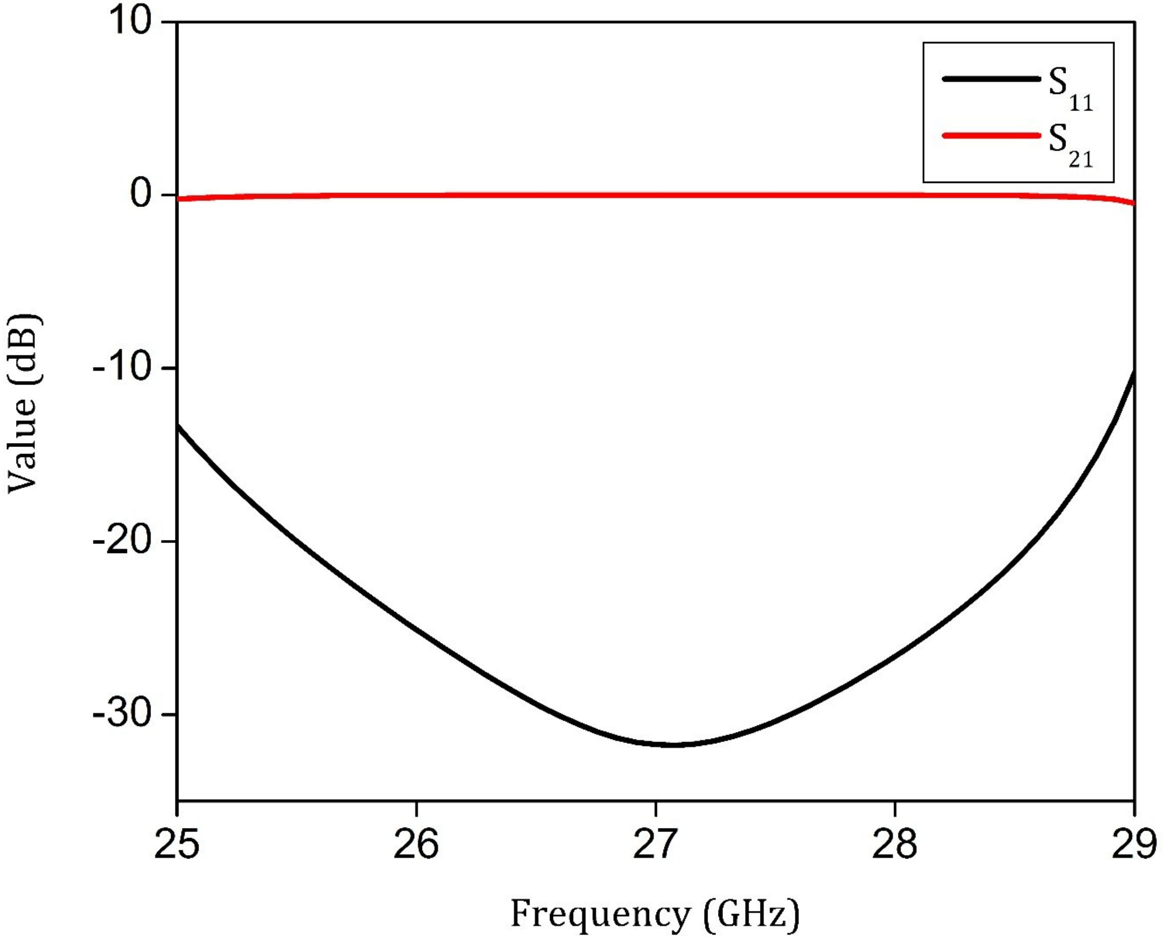
Unit cell with simulation model


2.2
2.2
1.35
1.4
0.14
1.28
1.35

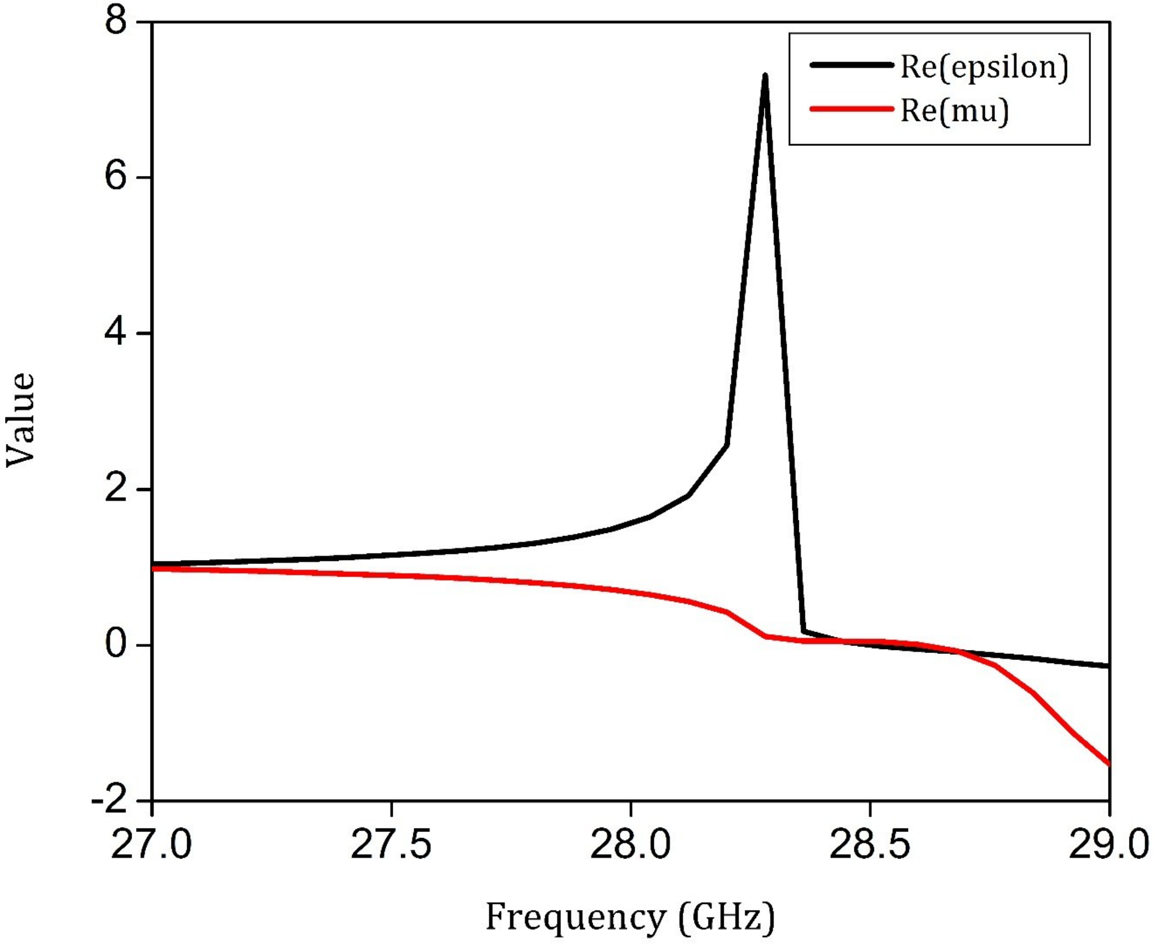

Perfect H
Port 1
Port 2
Perfect E
Perfect H
H
E
k

Karthikeya, G. S., Mahesh P. Abegaonkar, and Shiban K. Koul. "Pattern diversity of path loss compensated antennas for 5G base stations." *International Journal of RF and Microwave Computer-Aided Engineering*: e21800.

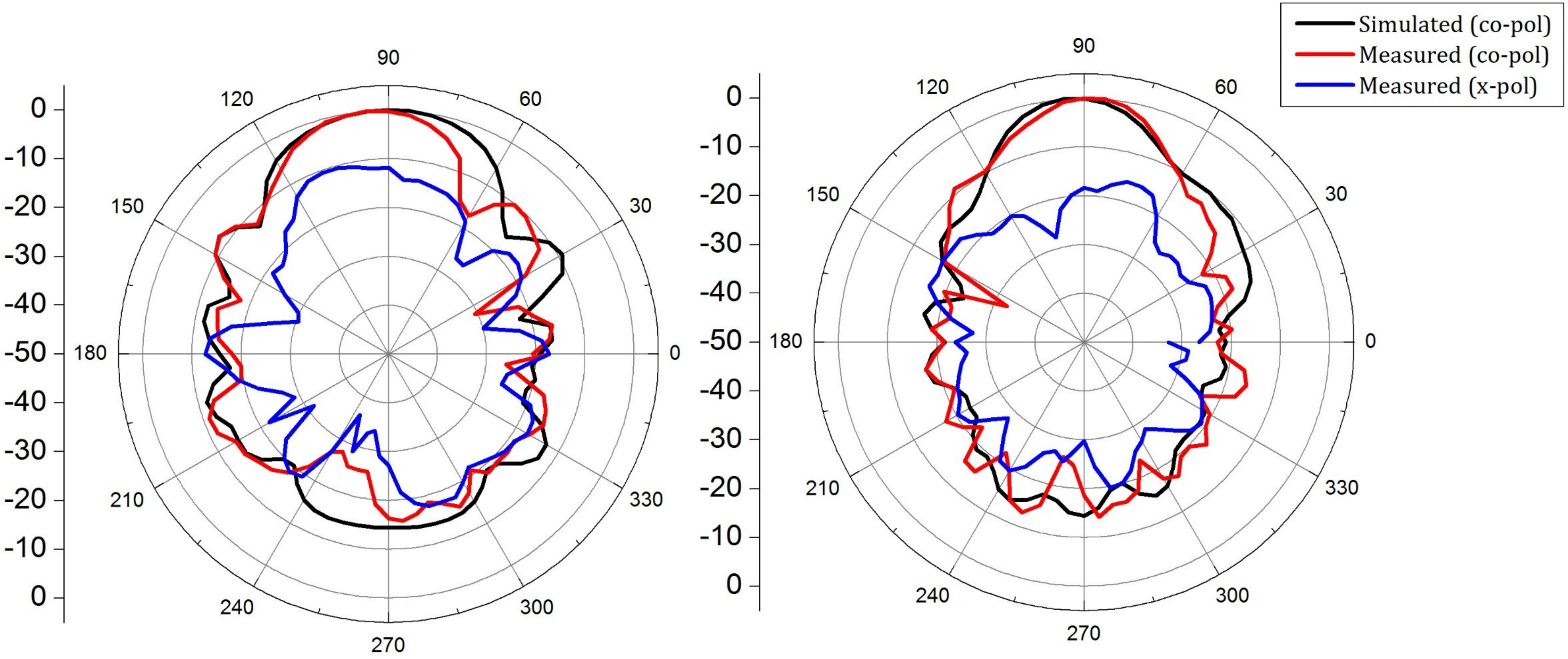
$|S_{11}|$ and $|S_{21}|$



Extracted μ and ε



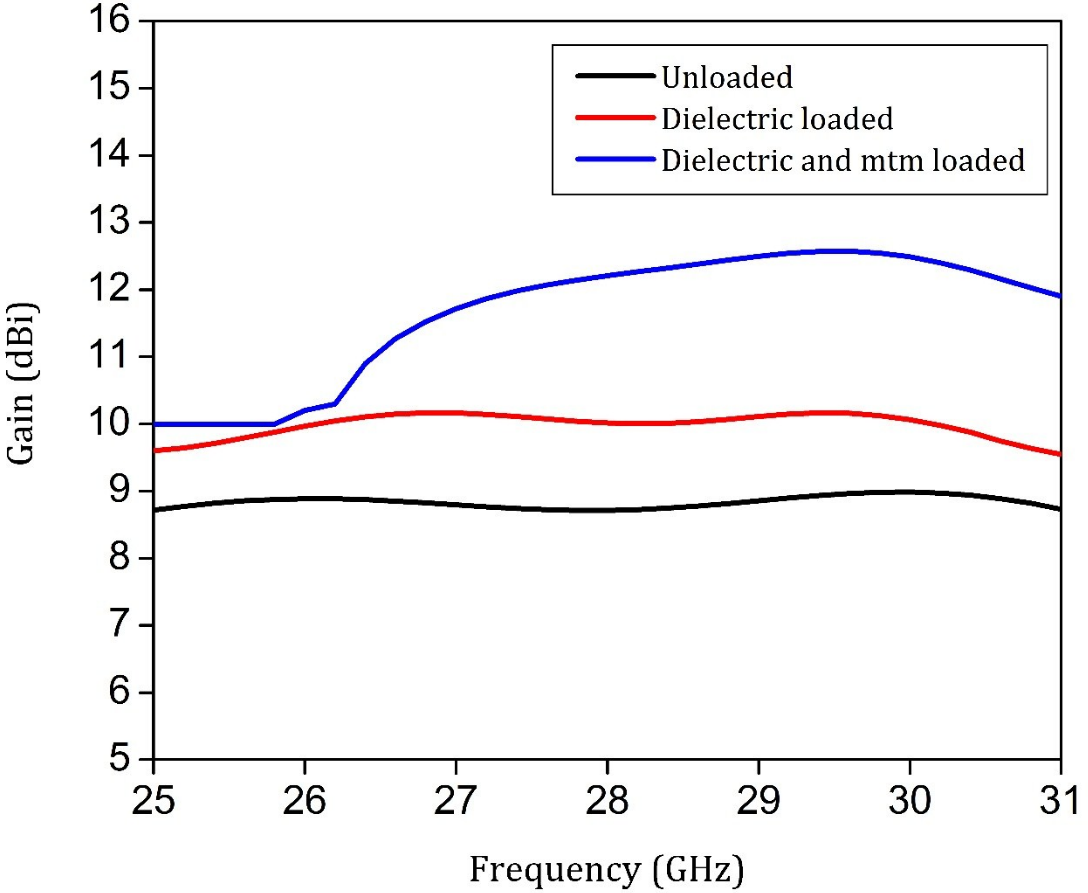
E-plane Patterns at 28 and 30 GHz



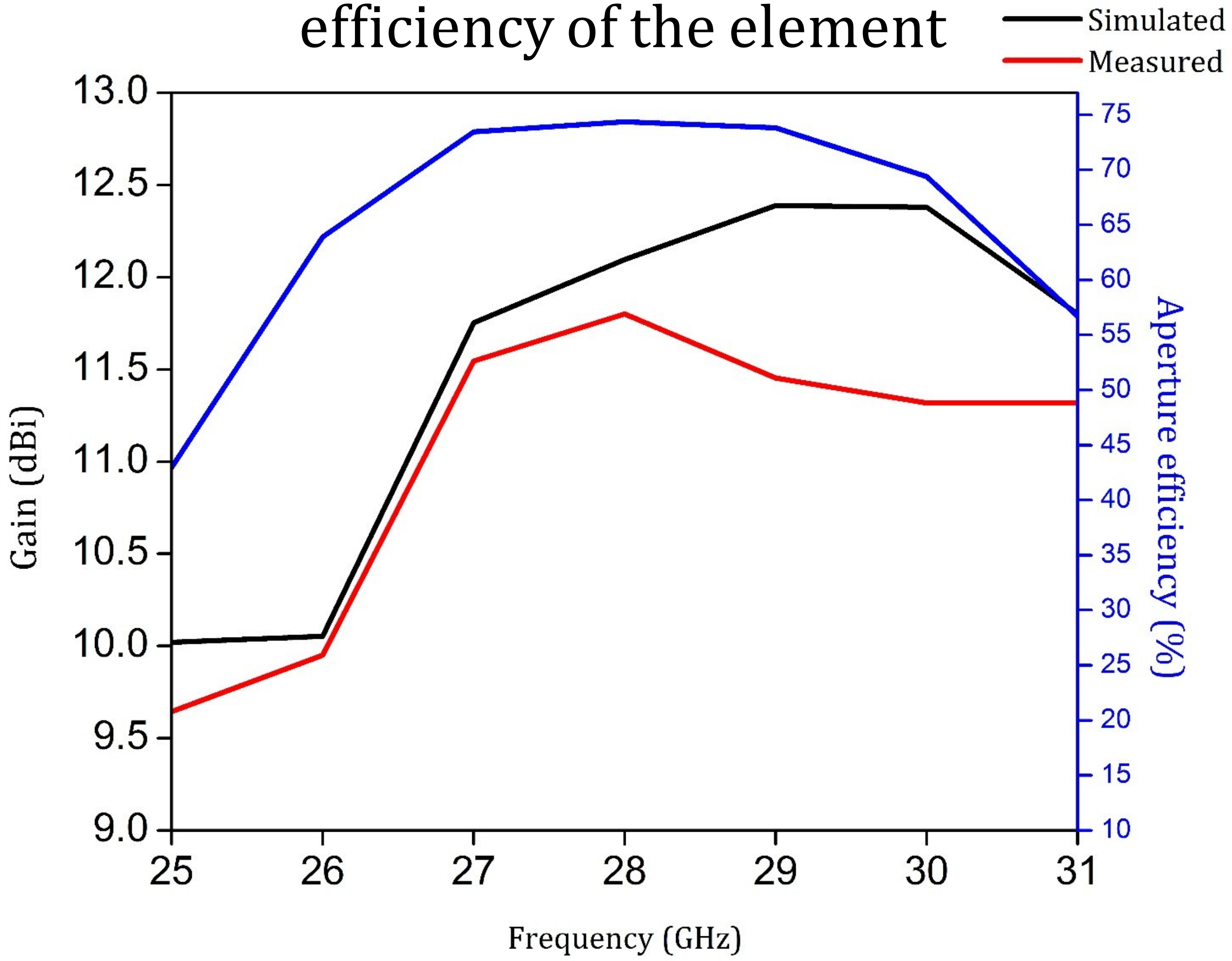
YZ Plane

XY Plane

Gains of the different strategies



Gain and Aperture efficiency of the element

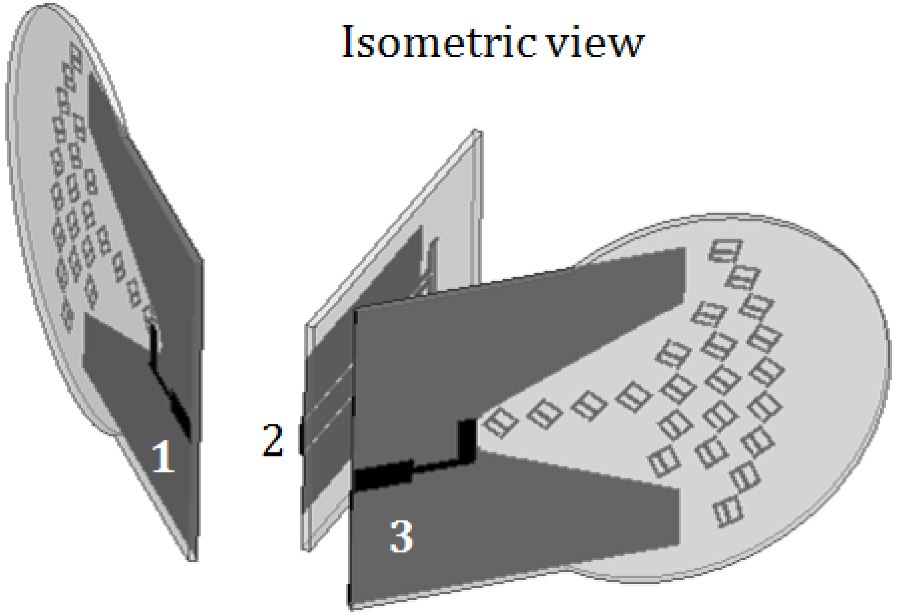


Comparison with reported articles

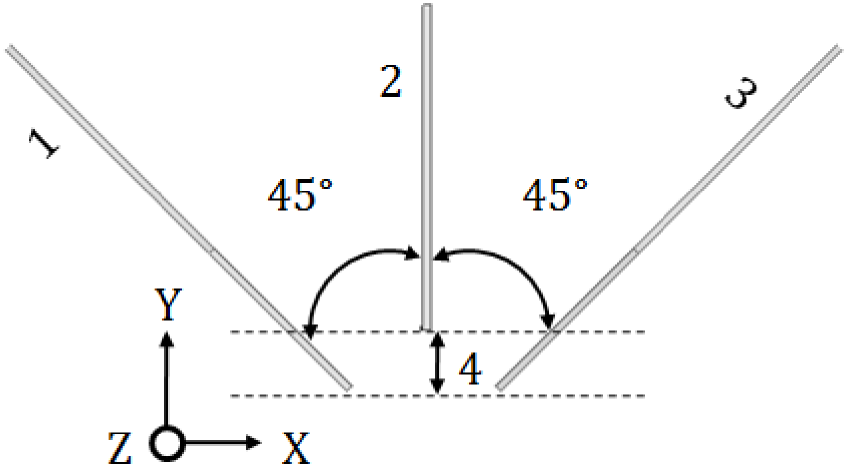
Ref.	Planar	freq. (GHz)	Gain (dBi)	1 dB Gain BW (GHz)	Aperture Efficiency
TAP ’15	Yes	15	12	10-20 (66%)	26.6%
TAP ’15	No	12	12	12-16(28.6%)	74%
PIER ’11	No	10	14	9.5-12(23.2%)	59.5%
TAP ’17	Yes	61	20.3	58-63(8.2%)	63.06%
Proposed	**Yes**	**28**	**12**	**26-32(20.7%)**	**75%**

Schematic of the pattern diversity module

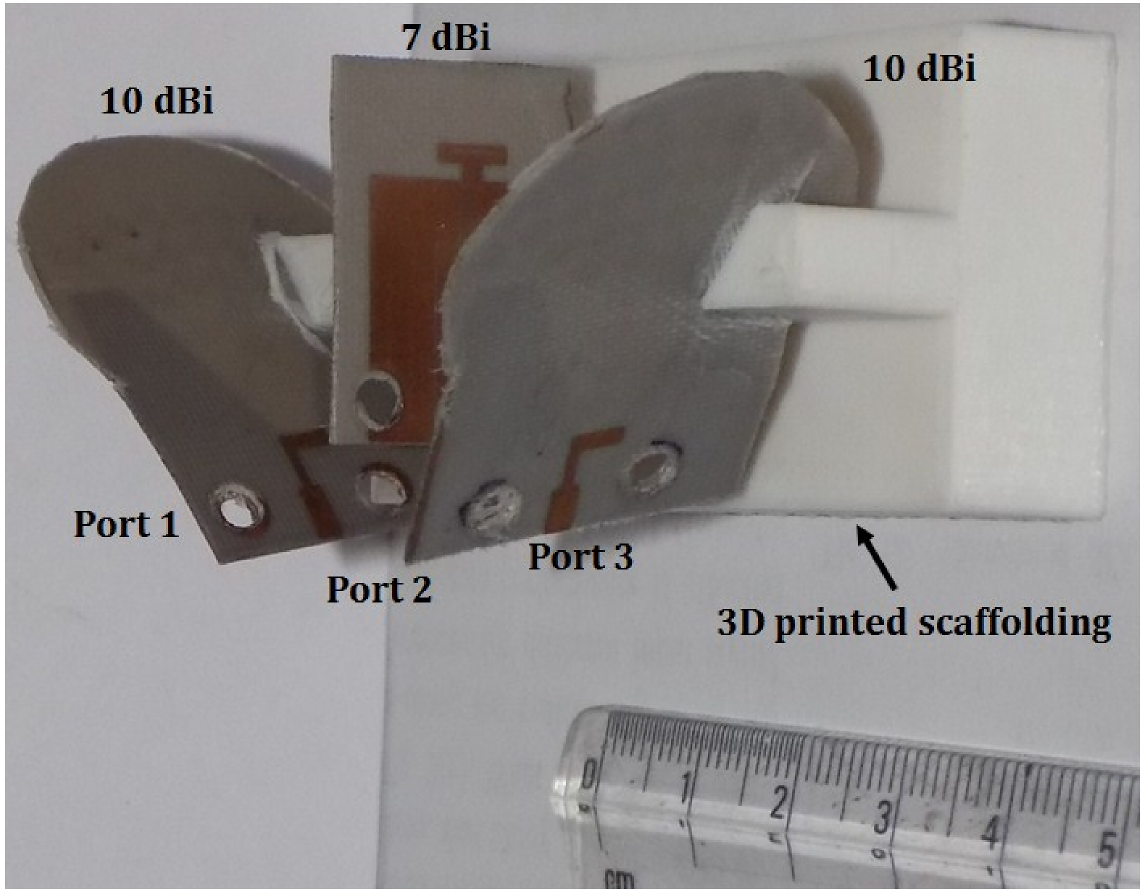
Isometric view



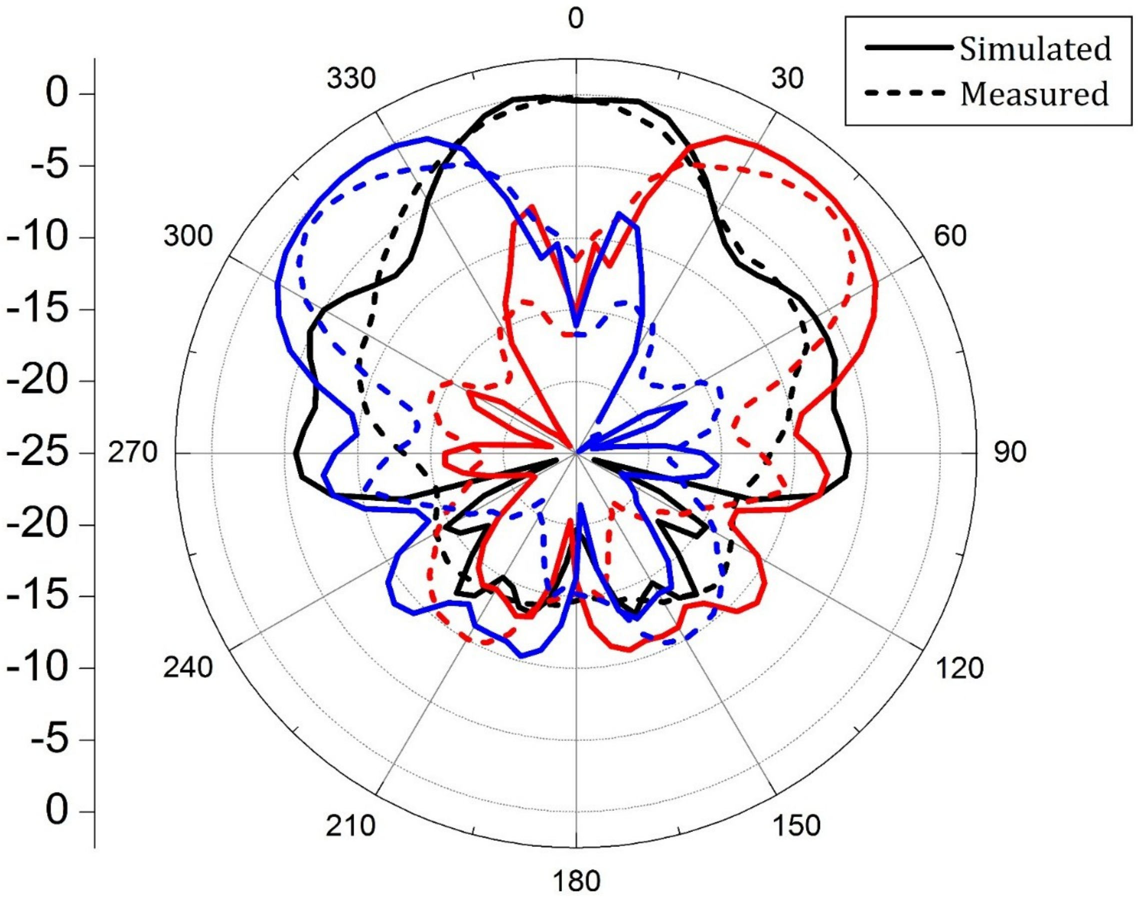
Top view


1
2
3
45°
45°
Y
4
Z
X

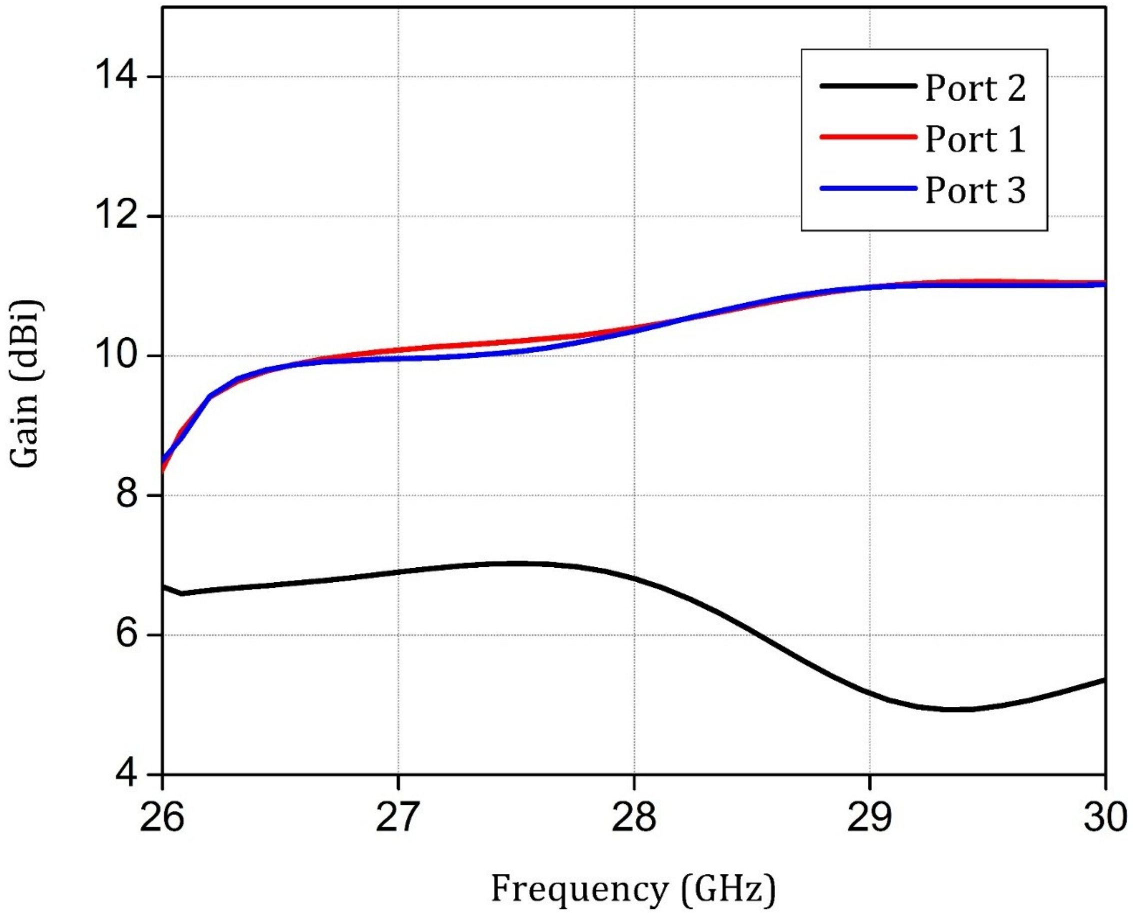
Fabricated prototype


7 dBi
10 dBi
10 dBi
Port 1
Port 2
Port 3
3D printed scaffolding

Patterns of the module at 28 GHz



Post integration Gains



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